Influence of tribological contacts on metal release and skin allergy

Lee, Seunghwan

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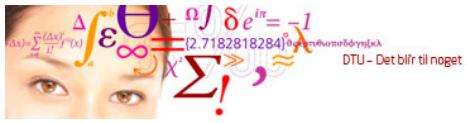


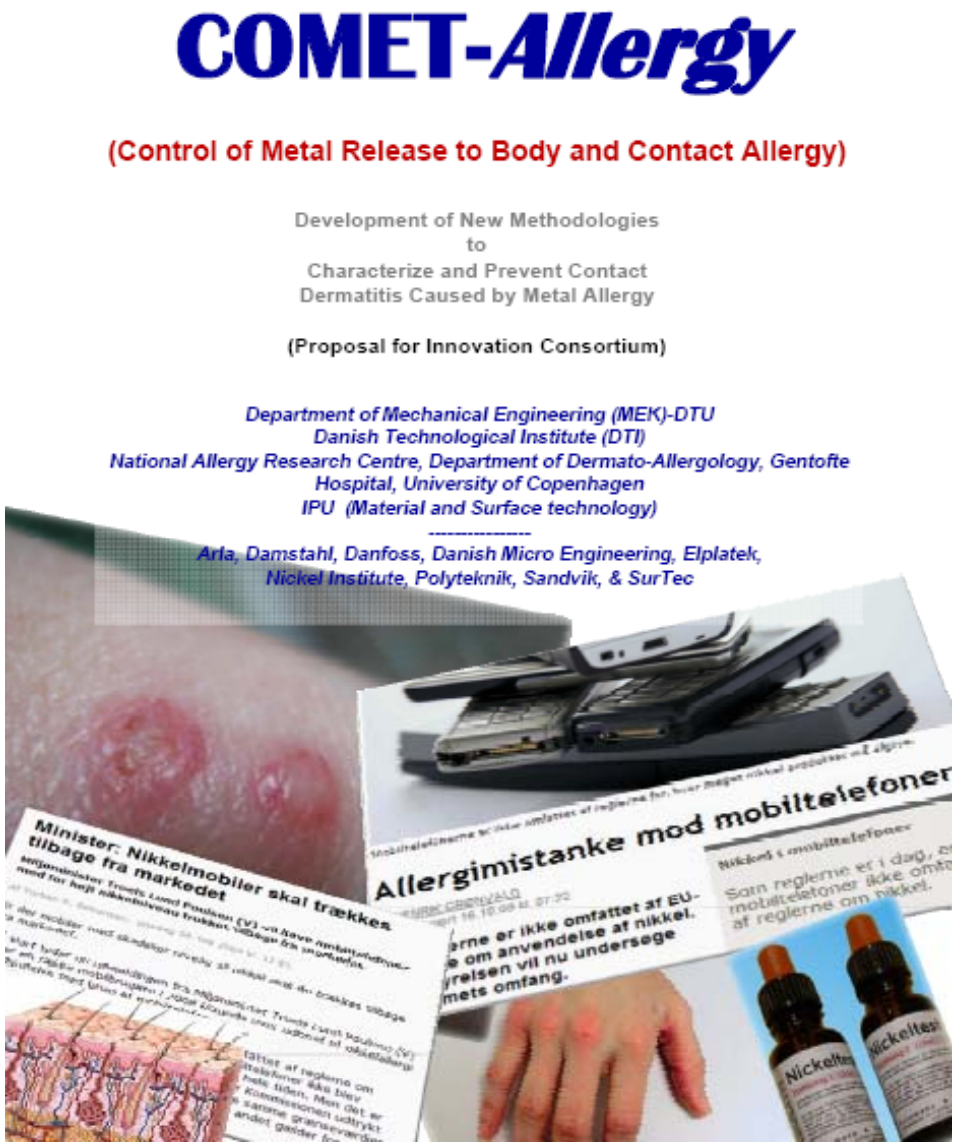
Influence of tribological contacts on metal release and skin allergy

Surfaces with potential risks of causing allergy - Challenges and Solutions

8th October 2009 at DTU, Kgs. Lyngby

Seunghwan Lee
Department of Mechanical Engineering
Technical University of Denmark

Outline



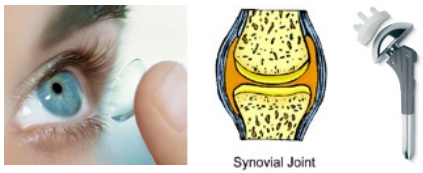
- Objectives of this talk
- Overview of skin tribology
- Role of tribological contacts on metal release
  - *A case study at DTU & GH*
- Focus of future research
- Summary & Conclusions

Skin Tribology: An overview

Tribology: the science and technology of interacting surfaces in relative motion

friction, wear, and lubrication

Oil, engineering materials



Biomaterials and implants

Micro-machine

- The term, "**skin-tribology**" appeared from late 1990's: very new challenge, new field

- Tribological contacts *involving human skin as (at least) one side of the interface*

: Counter surfaces- human skin, textile and many everyday goods

- Motions – touching, grabbing, holding, sliding etc.

Skin Tribology: Why care?

Conventional disciplines to deal with skin

- Medicine: Dermatology
- Cosmetic science and industry
- Textile engineering and industry etc.

Relevance

skin friction is intrinsically dealing with the (mechanical) interaction of skin with contacting objects and under varying environment (hydration, temperature, oil or moisturizers etc.)

Advantages

non-invasive and relatively simple

Expectations

- *Quantitative measurements of friction* at the interfaces involving skins
- Development of approaches to relieve ‘aggressive‘ tribological contacts (materials, lubricants, environment etc.)
- Help for early diagnosis of skin diseases or of the deterioration in skin functions at a stage that may not be easily discernable visibly

Skin Tribology: Classification

Skin tribology

Fundamentals

- How to measure skin friction

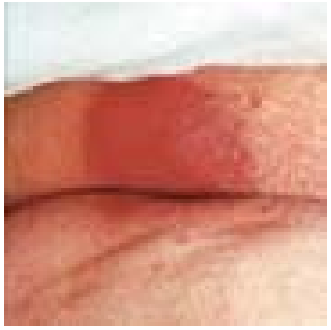
- Parameters to influence the skin friction

Biomedical engineering

Personal Care products

Skin Tribology as Biomedical Engineering: Decubitus Ulcers

Friction at the skin/textile interface for prolonged contacts


→ Choice & development of “comforting” textiles

(hospital textile, anti-decubitus prototypes)

→ Development of possible lubricants in combination with textiles

Fabrication, characterisation and tribological investigation of artificial skin surface lipid films
L.-C. Gerhardt, A. Schiller, B. Müller, N.D. Spencer, S. Derler
Tribology Letters; 2009; 34(2) pp 81-93

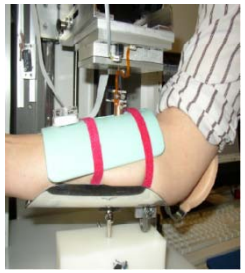
Influence of epidermal hydration on friction of human skin against textiles
L.-C. Gerhardt, V. Strässle, N.D. Spencer, S. Derler
Journal of the Royal Society Interface; 2008; 5(28) pp 1317-1328

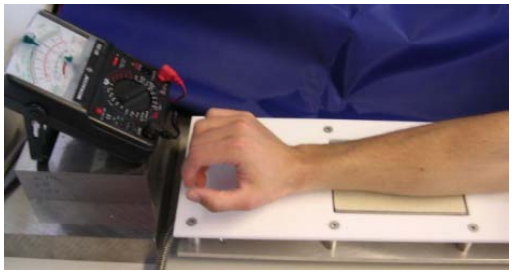
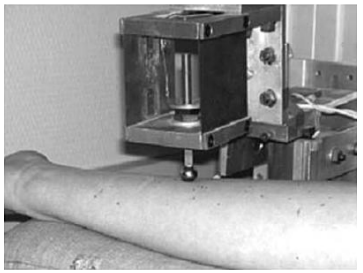
EMPA Materials Science & Technology

ETH

Skin Tribology: Technical challenges

Instability of load - *fluctuation*



⟶ Self-adjustment of the applied load: improvements in accuracy

Skin alternatives to the standard tribology instruments

Artificial leather Lorica®

Skin Tribology: What is known?

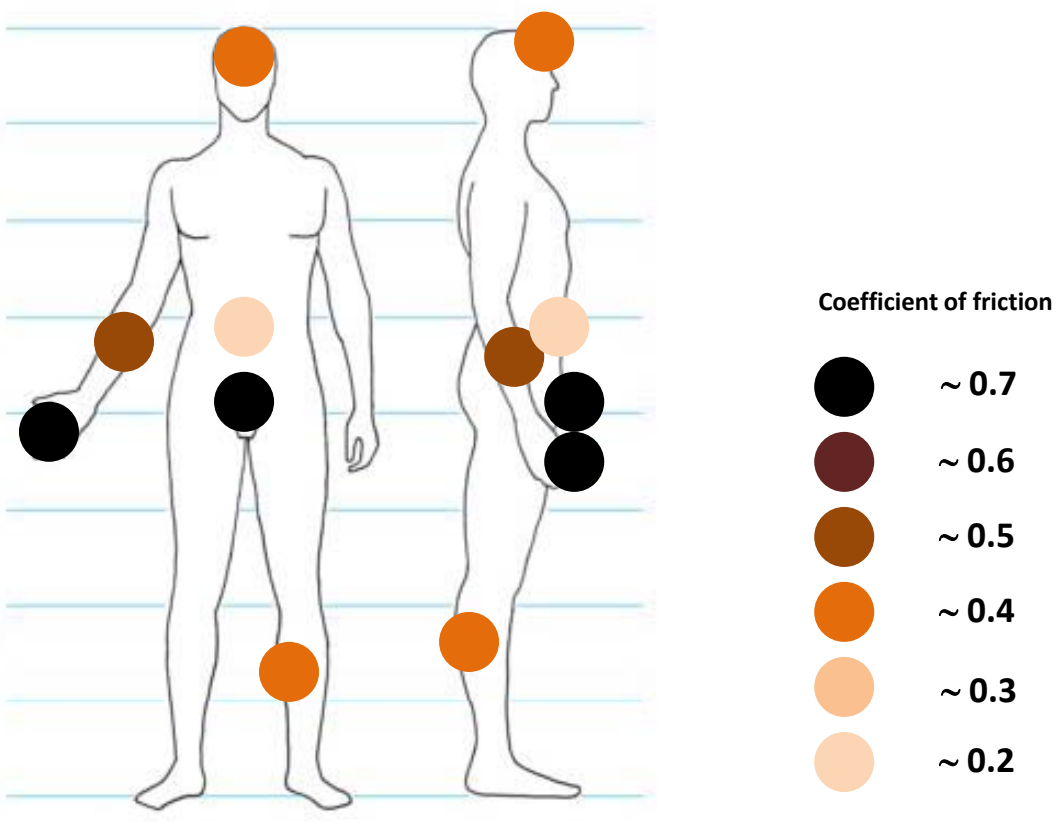
Intrinsic parameters

Gender and ethnic origin: nearly no difference

Age: (arguably) some variation

Anatomical sites: apparently influencing

Abdomen: 0.12
Fore head: 0.34
Leg: 0.40
Palm: 0.62
Crotch: 0.66
Forearm: 0.48



Skin Tribology: What is known?

Extrinsic parameters

Moisture (hydration): “drier skins” usually have lower friction

“hydrodynamic water films” also lower friction

Powders Tend to lower the friction

Emollients and moisturizers: Similar with water, but last longer

Skin tribology for metal allergy: A case study

Nickel-containing coins: a health risk for nickel-sensitive individuals?

British Journal of Dermatology, 2006, **155**. **pp. 1301-1303**

Studies on Tribocorrosion Explain **Low Nickel Release From Euro Coins**

Corrosion Management, March/April 2007. **pp. 9-13**

Morten S. Jellesen[1], Lisbeth Rischel Hilbert[1], Torkil Menné[2], Per Møller[1]

[1] Department of Manufacturing Engineering and Management, Technical University of Denmark, Kemitorvet, IPL, DTU-Building 204, DK-2800 Kgs. Lyngby, Denmark.

[2] Department of Dermatology, Gentofte Hospital, University of Copenhagen, Niels Andersensvej 65, DK-2900 Hellerup, Denmark.

Motivation: Allergy by Euro coins

nature International weekly journal of science

Nature 419, 132 (12 September 2002) | doi:10.1038/419132a

Metallurgy: High nickel release from 1- and 2-euro coins

Frank O. Nestle[1], Hannes Speidel[2] & Markus O. Speidel[2]

240-320 times higher than allowed under the EU Nickel Directive

Euro coins and the potential risk of nickel allergy

Paul-Guy Fournier[1], Thomas R. Govers[2], and Anne Brun[3]
[1] Laboratoire de Spectroscopie de Translation, Université Paris-Sud, Orsay
[2] Aecono Consulting, Paris
[3] Service Médical du Travail, Université Paris-Sud, Orsay

Nickel release from coins

Carola Lidén[1] and Stephen Carter[2]
[1]Occupational and Environmental Dermatology, Department of Medicine, Karolinska Institutet and Stockholm County Council, Stockholm, Sweden
[2]Laboratory of the Government Chemist (LGC), Queens Road, Teddington, Middlesex, TW11 0LY, UK

Release of nickel from coins and deposition onto skin from coin handling – comparing euro coins and SEK

Carola Lidén[1,2], Lizbet Skare[1] and Marie Vahter[3]
[1]Occupational and Environmental Dermatology, Department of Medicine in Solna, Karolinska Institutet, [2]Stockholm Centre for Public Health and [3]Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden

BBC NEWS WORLD EDITION

You are in: Health
News Front Page
Thursday, 12 September, 2002, 00:52 GMT 01:52 UK

Euro coins 'trigger allergy'

Motivation: Allergy by Euro coins

Apparent risk!

Immersion test

patch test

No confirmative indication of risk!

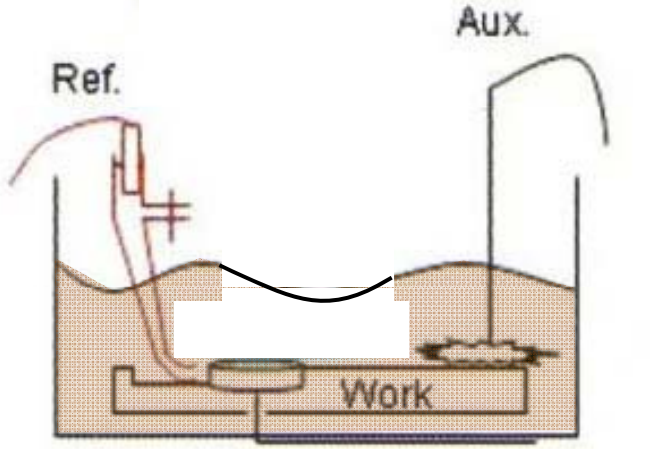
Possible reasons: Allergy by Euro coins

	Immersion Test	Patch Test	Handling of coins
Contact time	1 week	> 2 days	Seconds Minutes
Contact sites	No relevance	Back	Palms & fingers
Contact characteristics	No relevance	Stationary and prolonged	Dynamic and intermittent

Experimental setup: Corrosion and tribocorrosion

Load = 50 g/cm2

Speed = 60 rpm



Counter surface:
washable leather

Artificial sweat

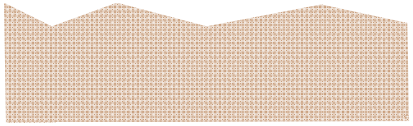
NaCl 0.3 wt%
Lactic acid 0.1 wt %
Urea 0.1 wt %
pH 6.5 +/-0.1

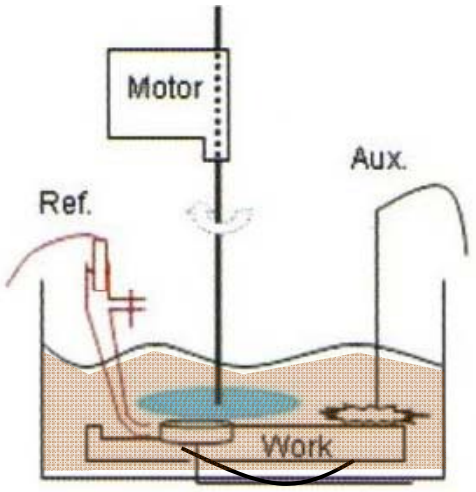
Results: Immersion test (confirmed)

Samples	Nickel release [0.5µg/cm²/week]	Nickel release vs. limit value: [0.5µg/cm²/week]
Cu75 Ni25	98,9	198
Cu75 Zn20 Ni5	18,5	37

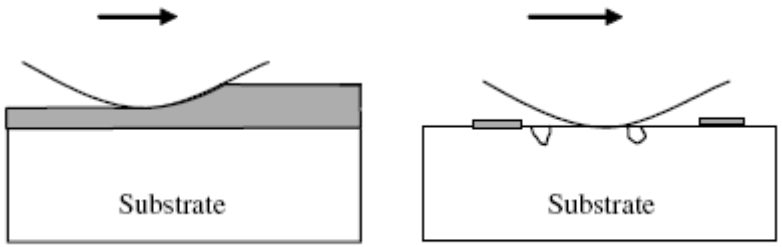
Results: Corrosion and Tribocorrosion test

Test method	Nickel release [µg cm^{-2} h^{-1}]
Corrosion	211 +/- 3
Tribocorrosion	37 +/- 16





For most metals, passivating oxide layer is removed during tribological contacts, and that accounts for enhanced wear in tribocorrosion compared to corrosion.



$T = W_0 + C_0 + \mathbf{S}$

T: total materials loss (release)
W_0: pure wear
C_0: pure corrosion
S: *synergetic effect*

A case study: Influence of tribological contacts on metal release

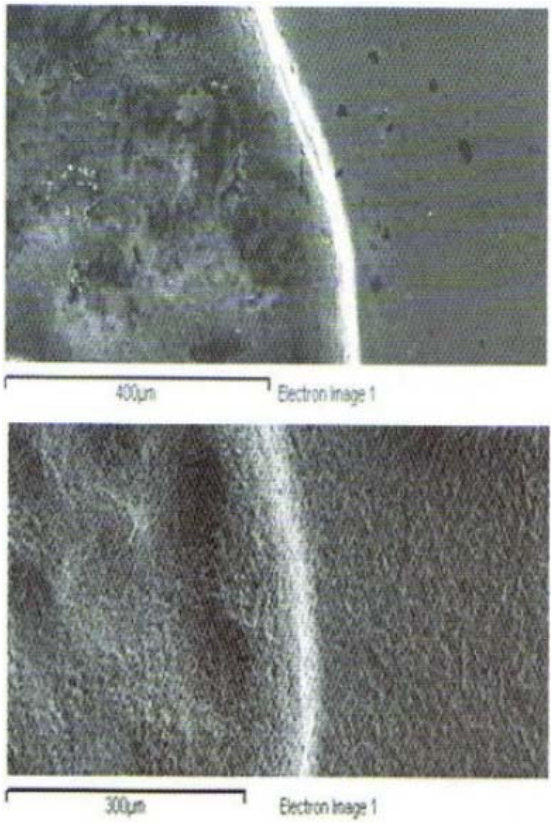


Figure 4: SEM micrographs of a 2-euro coin before tribocorrosion (above) and after tribocorrosion (beneath).

Substrate	Cu	Ni	Zn	O	C	Cl
Untreated	7,4	0,6	11,1	46,4	34,4	-
After corrosion	17,2	-	-	25,8	42,2	14,8
After tribocorrosion	5,7	-	1,0	29,5	63,8	-

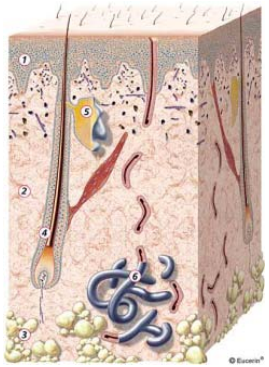
Figure 5: XPS survey scan of the Cu75 Zn20 Ni5 alloy indicating the relevant binding energy peaks of main elements present on the surface. The untreated coin has been polished with SiC grit 500, washed with distilled water and dried.

The coin exposed to corrosion has been polished likewise and then immersed in sweat at open circuit potential for 15 min and subsequently held at 500 mV SHE for 1 hour. The coin exposed to tribocorrosion has been exposed to wear during both the 15 min open circuit potential monitoring and subsequently chronoamperometry test at 500 mV SHE.

Negative synergism: different transport kinetics i.e. leather act as a diffusion barrier between the electrolyte solution and coin surface and precipitation of a passivating layer.

Friction on human skin?

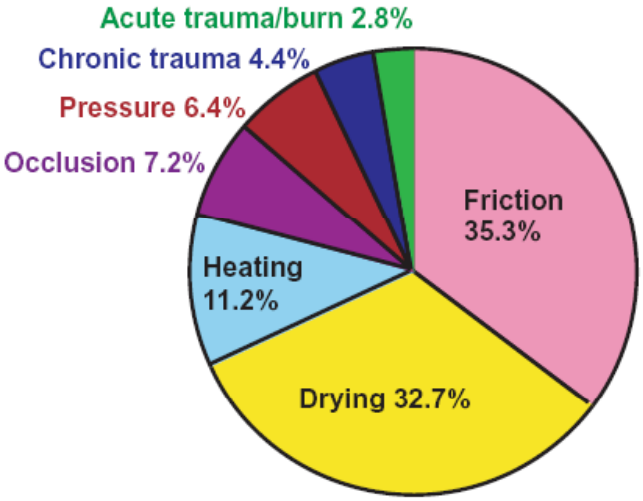
More complex surface chemistry



hydrolipid film

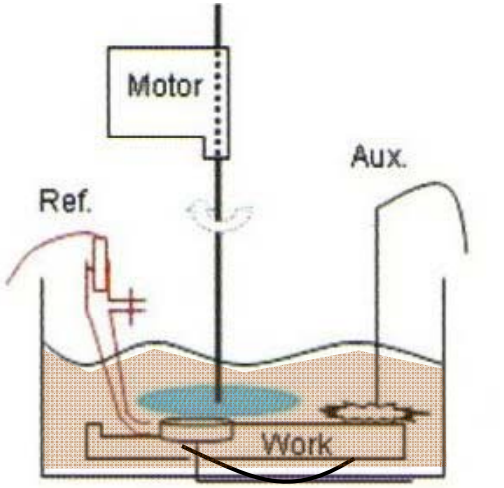
- *Sweat*
- Epidermal lipids
- Sebum

Physical Irritant Contact Dermatitis (PICD)



British Journal of Dermatology 2002; **147:** 270–275.

Future research focuses: full range of tribology parameters



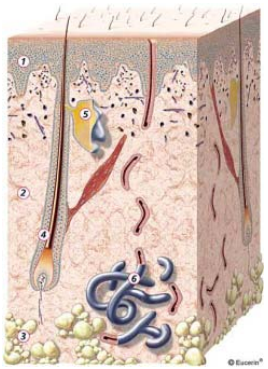
Variation of

(1) Contact time, load, and speed

(2) Counter surfaces: hardness, surface chemistry, and geometry

(3) Chemical composition of the objects

Future research focus: Skin alternatives



in-vivo

in-vitro

Mechanical properties

Elastomers (silicone, PU, etc.)

Surface topography

Roughness, pattern/texture

Surface chemistry

hydrolipid film

Future research focuses: Tribometer-to-Skin than Skin-to-Tribometer

Hand-held tribometer

http://www.kett.com/prod10.asp

?

Moisture content (Corneometry)

The Kett 94Ai Tribometer is the world's first and only handheld portable static friction analyzer. Battery operated, the unit is placed on the part to be tested. When the "start" button is pressed, a precision voice coil motor tries to push the test plate. Force is increased over time. When the test plate begins to move (overcoming static friction), the system calculates the reactive force and computes the coefficient of static friction u_s. Tests take less than thirty seconds. The integrated averaging function allows for rapid determination of the average coefficient of friction on the most heterogeneous materials. The flexible design allows for different measurement surfaces and contours to be attached, allowing simulation of most test surface interfaces. A three-year warranty is standard.

Thanks for your attention!